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Monument Damage Hazards & Rehabilitation Technologies

Proceedings

UNDER THE AUSPICES OF I.G.C.M.M.

Volume I

31 May – 2 June, 2010

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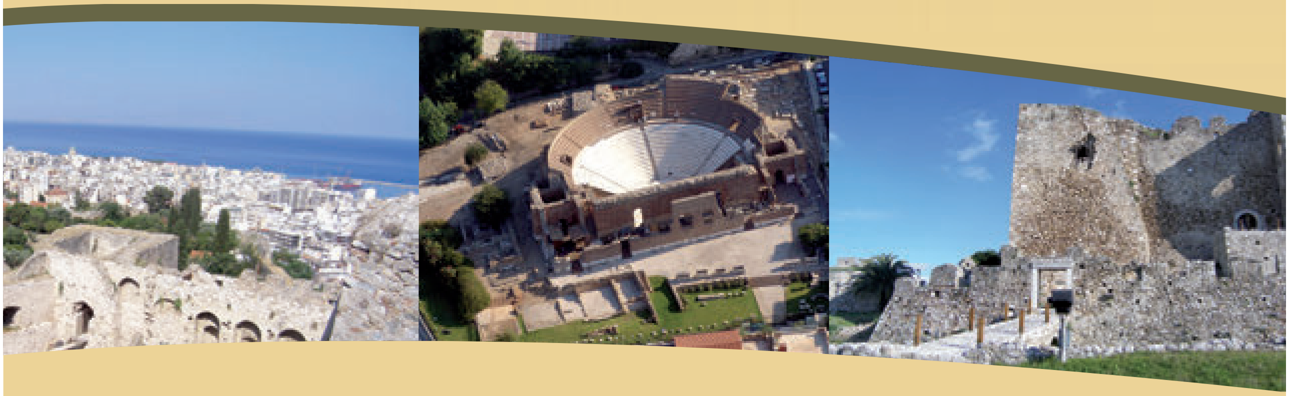

Technical Chamber of Greece

8th INTERNATIONAL SYMPOSIUM ON THE CONSERVATION OF MONUMENTS IN THE MEDITERRANEAN BASIN

May 31 - June 2, 2010 - Patras, Greece

MONUMENTS DAMAGE HAZARDS AND REHABILITATION TECHNOLOGIES

PROCEEDINGS

VOLUME I

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Organization

The 8th International Symposium on the Conservation of Monuments in the Mediterranean Basin was organized by:

- National Technical University of Athens (NTUA, School of Chemical Engineering, − Materials Science and Engineering Section
- University of Patras
- Technical Chamber of Western Greece

under the auspices of:

The International Group on the Conservation of Monuments in the Nediterranean Basin (I.G.C.M.M.)

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Presentation

These volumes contain the papers presented at the 8th International Symposium on the Conservation of Monuments in the Mediterranean Basin held in Patras, Greece, from 31 May until 2 June, 2010. The Symposium, following previous symposia in Bari (1989), Geneva (1991), Venice (1994), Rhodes (1997), Seville (2000), Lisbon (2004), and Orléans (2007), was organized by the National Technical University of Athens (NTUA, School of Chemical Engineering, Materials Science and Engineering Section), the University of Patras and the Technical Chamber of Western Greece.

This International Symposium, provided a forum for scientists, technicians and experts, in the area of conservation and restoration of monuments, to present their work and exchange ideas and experiences. During the Patras 2010 Symposium, new opportunities were presented and deepened the existing knowledge base regarding the problems of cultural heritage.

The theme chosen for this Symposium, "Monument Damage Hazards and Rehabilitation Technologies", refers to the natural and anthropogenic hazards on monuments, as well as to the technologies used for damage rehabilitation. A large array of topics enabled scientists to discuss and share the main problems they encounter in their monument projects in the Mediterranean Basin. Thus, the Symposium addressed restoration engineers, architects, geologists, restorers and conservators of stone artifacts and other specialists in the decay and restoration of monuments, as well as archaeologists, art historians and scientists in the fields of physics, chemistry and biology. Furthermore, the Symposium aimed at intriguing the interest of both cultural institutions involved in heritage management and manufacturers of building treatment products.

In this Symposium more than 350 authors, attendees, exhibitors and sponsors came from Belgium, Canada, Cyprus, Finland, France, Germany, the Great Britain, Greece, India, Iran, Italy, the Netherlands, Portugal, Serbia, Spain, Tunisia, Turkey, etc. to participate.

All the papers were critically reviewed by the members of the Scientific Committee, to whom I would like to attribute my deepest gratitude for all their essential effort and co-operation in this very important aspect of the

Symposium. The papers in these volumes are arranged according to the topics and alphabetically ordered.

I would also like to express my special thanks to Dr. Dimitrios Kouis (Computer Engineer), Dr. Nico Avdelidis (Materials Engineer), Eleni Cheilakou (Chemical Engineer), Panayiotis Papandreopoulos (Chemical Engineer) and Panagiotis Theodorakeas (Chemical Engineer) for their crucial contribution to the preparation and edition of these volumes.

Many thanks should be given to the Organizing Committee members for organizing the sessions and for their excellent work, as well as the secretariat, Mrs Kanella Pouli and Mrs Mary Sypsa, whose contribution is considered of utmost importance for the success of the Symposium. To them great thanks are attributed by the IGCMM.

Last, but not least, I would like to express my thankfulness to all sponsors for their financial support.

Professor Maria Koui
Coordinator of the Organizing Committee

CONTENTS

STATIC REQUIREMENT AND TYPE'S COMPLEXITY IN THE DIAGNOSTICS PHASE

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Keywords: Structural complexity, static requirements, refurbishment interventions, diagnosis phase, conservation

Abstract

The preservation of an historical building, whatever its architectural and/or artistic value, is more appropriate as it is deeper the building knowledge, its development, its materials and constructive techniques. So the preliminary phase of a restoration intervention is the data acquisition, the direct characteristics and conditions recognition of the building and the survey of significant alterations. The reasons that cause these modifications, in great number of cases, are not respectful of the building static efficiency, so its static requirement could be weakened. In fact, a very high percentage of building damages is attributable to these modifications are not always sufficiently respectful of a structural balances consolidated over time. The study focuses on the analysis of the restoration intervention on two trilobate pillars that separate the central space from the presbytery in the Cathedral of Matera, *a little city in the southern part of Italy. Through the use of sonic tests - carried out despite the complexity of the shape of a building structural and constructive elements that characterizes these pillars – it was possible to show the effectiveness of the implemented intervention, highlighting its critical points and its weaknesses. The research aims to show how - despite the type complexity of some structural elements of a building - becomes essential an appropriate building knowledge to realize interventions that are able to operate a correct restoration interventions of a building and, at the same time, that it is respectful of its type and material peculiarities.*

Introduction

The preservation of an historical building, whatever its architectural and/or artistic value, is more appropriate as it is deeper the building knowledge, its development, its materials and constructive techniques.

In fact, the protection and conservation of monumental heritage represent varied and sometimes even alarming aspects; however, they help us to identify the commonly called "architectural emergency". This is essentially related to the size and the great number of cases to resolve and – together - to the limited availability of usable resources and experiences.

So, it's necessary to optimize in a better way the just limited financial and temporal resources, giving to our monuments the respect that compete themself. Faced with a degraded monument, the renovation designer can meet three main questions: "if" to perform a restoration, "where" to perform a restoration and "how" to perform a restoration.

To these questions it is possible to add another one that regarding the economic aspect: "when" to perform a restoration intervention.

In order to respond adequately to these questions, it is necessary to advance "step by step", through easily defined procedures, as the degradation identification, the causes determination, the assessment of residual safety and, finally, through the suitable intervention choice and the definition of its executive method. So the preliminary action is the research of all information about the monuments; these informations are required to describe the structure and all the transformations that it has suffered; in this situation, it becomes essential the history knowledge of the building, from its construction until the last modification that it has undergone.

In the first phase of data acquisition, the direct recognition of the building characteristics and the survey of the checked alteration, should be complemented by research of design documentation and of events that have affected the structure during all its life cycle.

Shape's Complexity and Static Balance

The structural and static complexity of the historical building represent the more important characteristics of each monuments.

In fact, in the last years, the necessity to operate interventions of masonry structural reinforcement has become increasingly urgent, stimulating both by the objective requirements related to increased degradation of the monumental buildings and by a greater interest towards conservation theory.

The restoration criteria, in fact, impose severe restrictions on the possibility to realize a different intervention types but - at the same time - stimulate the choice of the suitable solutions.

Naturally, these solutions will sought in changes to realize to the main parameters that constitute the mechanical part of the structure (i.e. the geometry, material and loads).

In fact, changes, modifications, partial demolition and reconstruction are quite frequent in a building history, especially in a monumental building. A lot of monuments, in fact, have modified its shape and its structural and functional organization in its life cycle, realizing - for example – of superelevation or addition part of construction, modifying the static distribution of the force, etc.; a very high percentage of building damages is attributable to these modifications are not always sufficiently respectful of a structural balances consolidated over the time.

These changes led new structural stresses - not always proportionately allocated over the building structure – and very often they led a new shape and aesthetical characteristics.

Thus, the geometry changes are surely the most effective (i.e. the increase of stiffness obtained with the increase of resistant section or by adding a constraint). The criterion for an intervention on the geometry was almost abandoned, although structurally good; the practice of complete replacement of degraded elements with other more or less "similar" to the original is realized very often, while frequently are offered - in parallel to existing structures - structures that are able to bear the load of the structure, in case of triggering the collapse.

It is considered, therefore, that the elaboration of a proposed consolidation intervention is essential to achieve different objectives that ensure the maximization of the monument respect.

These objectives are:

1. to allow maximum persistence of the original material, limiting at minimum the transformations (demolition, replacement, etc.);
2. to recognize the variable "time" as a positive sign that are able to add value to the building, which must be understood as a "palimpsest" on which are layered different elements;
3. to use objective knowledge that are closely related to the building or specific pathological situation;
4. to make decisions on the basis of technical assessments, supported by an in-depth knowledge and never based on historical, critical or aesthetic judgments;
5. to realize recognizable and reversible interventions, in order to make possible in the time control, monitoring, additional maintenance (i.e. the introduction of new technologies or systems more effectively);
6. to establish a correct maintenance program over time, not aimed at any replacements intervention at predetermined intervals, but based on observation of the phenomena, in order to prevent possible dangerous situations and slow down the aging process of the building.

The Case Study

This research focus upon the Cathedral of Matera - a little city in the southern part of Italy (Figure 1), a massive architectural structure, built at the end of the XIII century.

Figure 1: The Matera Cathedral

In Apulian Romanesque style, it keeps its formal and architectonic connotations almost unchanged outside, even though some interventions have substantially changed the inside style. It does not show any plain deterioration signs of its static structure, but it is plain a pathology outside.

The study focuses on the analysis of the restoration intervention on two trilobate pillars (Figure 2) that separate the central space from the presbytery.

Through the use of sonic tests - carried out despite the complexity of the shape of a building structural and constructive elements that characterizes these pillars – it is possible to show the effectiveness of the implemented intervention, highlighting its critical points and its weaknesses.

In fact, with the sonic tests are measured and analyzed the characteristics of propagation of elastic waves inside the walls with the aim to understand the homogeneity of the structure, the changes of material properties caused by degradation, the structural defects - such as cavities or cracks – and the magnitude of the resistance of materials.

Figure 2: The trilobate pillars

This test is carried out by measuring the time and speed of the wave that passes through the wall, a mechanical impulse generated by a transmitter and picked up by a receiver.

The speed of an elastic waves in a homogeneous, isotropic and perfectly elastic, is linked to the dynamic elastic modulus Ed, by the following relation:

in which: $E_d = v^2 \cdot d \cdot \frac{(1+\nu)(1-2\nu)}{(1-\nu)}$

Ed = dynamic modulus in Pa
v = speed of the wave in ms-1
ν = Poisson modulus
d = density of the elements in kgm-3

The elastic wave loses energy in his propagate, and this is due to a decrease in the intensity related to the propagation law of the spherical type, while another decrease is the interface between the gap, where the energy is partly reflected and partly refracted.

High speed - closely proportional to the elasticity modulus and to the strength of the element - and short term indicate a compact structure (i.e. single body masonry or multiple body well connected), while discontinuities, fractures, porous materials are considerably lower speed and consequently increases time.

The test was performed on the above said columns, identifying different directions (Figure 3 and Figure 4) - at different heights - in order to cover the largest part of the surface; these directions would also consider the different materials connections, related to the particular shape of the pillars. Certainly this complexity became an important element to evaluate in order to operate a correct and precise evaluation of the investigations project.

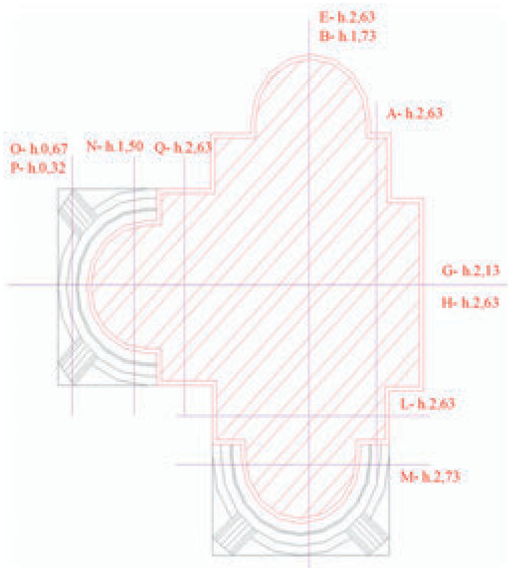

Figure 3: Sonic directions of investigations carried out on the left trilobate pillar

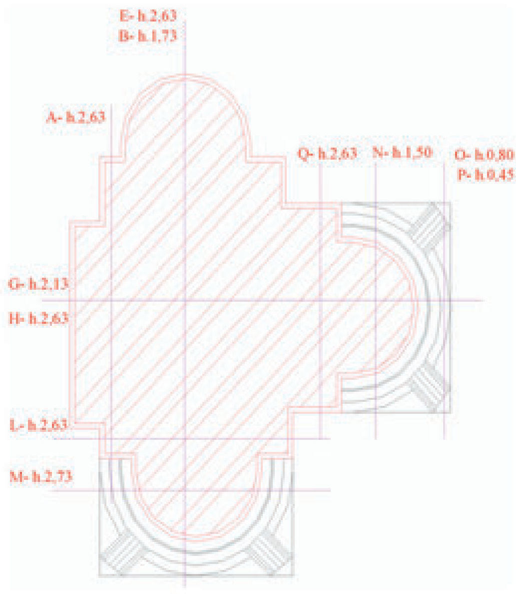

Figure 4: Sonic directions of investigations carried out on the right trilobate pillar

Table 1: Sonic tests results on the left trilobate pillar

As			Bs									Es		
s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)							s(m)	t(us)	V(m/s)
	942			1315									1374	
	918			1321									1285	
	944			1317									1295	
	921			1352									1281	
	947			1331									1345	
1,67	933	1686,902	2,37	1346	1763,13							2,37	1332	1768,393
	922			1343									1340	
	909			1348									1376	
	902			1372									1345	
	941			1355									1363	
	963			1362									1361	
	919			1367									1362	
			Gs			Hs						Ls		
			s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)				s(m)	t(us)	V(m/s)
				1199			1113						613	
				1212			1002						634	
				1172			1023						628	
				1116			1017						691	
				1147			1020						639	
			1,87	1141	1598,837	1,87	1036	1823,145				0,95	644	1434,395
				1173			1025						661	
				1147			1039						692	
				1176			1051						668	
				1161			1027						676	
				1192			1016						692	
				1188			1033						690	
Ms			Ns			Os			Ps			Qs		
s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)
	371			448			341			391			553	
	407			498			338			393			531	
	400			415			349			389			573	
	398			429			350			382			563	
	412			495			348			381			575	
0,61	432	1474,142	0,56	431	1494,075	0,96	343	2785,839	0,96	381	2442,748	0,84	633	1372,998
	394			353			351			394			657	
	384			354			342			399			630	
	472			354			350			405			636	
	406			348			344			405			656	
	435			354			336			401			648	
	482			379			343			395			651	

usually characterize those walls not strongly degraded and presence of voids.

From the observation of results, it is possible to note that lower values are not recorded along the longest paths - such as those linking the two semi-columns or the semi-column with the pilaster - but along the shortest paths within the elliptical shape. This leads us to assume a more widespread damage, also visible on the surfac of the pillars.

While, the investigations on the right pillar (Tab. 2) highlight of values between 1450 m/s and 1850 m/s at different levels and in the range 1.50-2.73, which usually characterize those walls not strongly degraded and presence of voids. Even the pillar right, by the observation of partial results show that higher values are recorded along the longer trajectories (as above said), the lowest (about 1400 m/s) along the shortest paths within the elliptical shape. This leads us to do the same considerations of the left pillar.

Table 2: Sonic tests results on the right trilobate pillar

Ad			Bd			Cd			Dd			Ed		
s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)
	886			1572									1269	
	871			1356									1267	
	855			1361									1267	
	879			1424									1300	
	899			1358									1240	
1,49	848	1694,337	2,31	1434	1644,713	2,31		#DIV/0!	2,31		#DIV/0!	2,31	1243	1828,4
	894			1427									1019	
	883			1418									1261	
	883			1423									1249	
	870			1427									1271	
	894			1333									1284	
	922			1390									1292	
Fd			Gd			Hd			Id			Ld		
s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)
				1052			1037						620	
				1002			957						664	
				1043			976						650	
				1046			956						679	
				1011			937						654	
1		#DIV/0!	1,81	1011	1750,822	1,81	960	1883,259	1		#DIV/0!	1	683	1477,541
				1005			945						675	
				1005			947						724	
				989			990						689	
				1037			983						701	
				1096			906						709	
				1116			987						679	
Md			Nd			Od			Pd			Qd		
s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)
	452			444			394			472			474	
	422			424			393			452			521	
	456			440			434			436			560	
	461			416			422			433			546	
	411			416			412			472			552	
0,67	436	1459,059	0,60	406	1440,23	0,98	407	2401,372	0,98	436	2164,780	0,83	543	1442,726
	485			402			416			407			567	
	466			415			403			472			648	
	459			410			418			440			565	
	452			418			406			452			623	

Figure 5: Damage visible on the surface of the pillars

Sonic tests were carried out also on the stone base of the pillars using the same investigation test. The measured values are greater than 2000 m/s that indicates a good state of preservation.

The research - applied on the above described pillars - is on going also for the other structural elements of the Matera Cathedral in order to provide a complete knowledge of the monument and to develop a suitable restoration intervention.

Conclusions

The research aims to show how - despite the type complexity of some structural elements of a building - becomes essential an appropriate building knowledge to realize interventions that are able to operate a correct restoration interventions of a building and, at the same time, that it is respectful of its type and material peculiarities.

The study aims to realize an applicative methodology more respectful of the monumental heritage, in order to avoid a simple acritical transposition of the calculation models in the recovery interventions.

This research can also contribute to increment the typology of the tests to carry out on the masonry; in fact, in relation to all the problems of tests and investigations (first of all the geometrical complexity), it is not necessary to have only one kind of survey, but an organic plan that consider in particular way the shape and the morphology of the investigated element, in order to have a more possible complete cognitive frame. Only in this way it is possible to interpret the real phenomena and give the necessary parameters to realize a correct intervention.

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